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Franz, J.; Papyrakis, E.

published in
Consilience: journal of sustainable development
2011

DOI (link to publisher)
10.1002/sd.446

document version
Publisher's PDF, also known as Version of record

Sustainable Development
Sust. Dev. **19**, 391–401 (2011)
Published online 25 January 2010 in Wiley Online Library
(wileyonlinelibrary.com) **DOI**: 10.1002/sd.446

Online Calculators of Ecological Footprint: Do They Promote or Dissuade Sustainable Behaviour?

Jennifer Franz[1] and Elissaios Papyrakis[2]*
[1] *School of Geography and Geosciences, University of St Andrews, St Andrews, UK*
[2] *School of International Development, University of East Anglia, Norwich, UK*

ABSTRACT
Ecological footprint (EF) indices estimate the impact of an individual's lifestyle on the planet by converting levels of consumption into the amount of land needed to sustain production levels and lifestyle choices. Several popular organizations (e.g. WWF, Global Footprint Network) now offer personalized EF calculators to help inform consumers of the impacts of their personal consumption habits. In this paper, we evaluate the most popular online EF calculators and find that, even when the most environmentally friendly options are adopted, for the majority of available indices, one still exceeds the planet's biocapacity levels. The absence of options to fully offset one's environmental impacts implicitly suggests that there is no truly sustainable level of consumption at current population levels, even under the most prudent consumer choices. Although all online EF calculators claim to be a tool for education to promote sustainable behaviour, their calculations suggest, to the contrary, that as consumers we may postpone but not necessarily prevent environmental catastrophes. Copyright © 2010 John Wiley & Sons, Ltd and ERP Environment.

Received 21 September 2009; revised 1 December 2009; accepted 7 December 2009
Keywords: consumer behaviour; ecological footprint calculators; green lifestyle; sustainability

Introduction

In the mid-1990s Wackernagel and Rees (1996, 1997) formalized the ecological footprint (EF) index that would give a comprehensible measure of human impact on the capacity of the planet to sustain the human population. Earth, at each point in time, provides a limited amount of ecologically productive land and marine area (i.e. cropland, pasture, forest and fisheries), which is counted in global hectares (gha). Currently this is estimated to be approximately 13 billion global hectares by the World Wildlife Foundation (WWF, 2008) and ongoing climate change and careless ecosystem management are expected to further reduce the global productive capacity of the planet due to water scarcity, overexploitation of renewable resources, soil erosion and desertification, amongst other problems. Humanity's demand on the biosphere in the form of resources to support consumption habits, as well as sinks to absorb the waste we generate, constitutes our global EF. In 2003, the human EF exceeded earth's biocapacity by approximately 3 billion global hectares and it appears that we have exceeded the earth's biocapacity in every single year since the mid-1980s (Wackernagel *et al.*, 2002); furthermore, the gap between the

*Correspondence to: Elissaios Papyrakis, School of International Development, University of East Anglia, Norwich NR4 7TJ, UK.
E-mail: e.papyrakis@uea.ac.uk

two has been ever increasing thereafter. If the earth's biocapacity were normalized to unity, our 2008 consumption levels would have corresponded to a planet more than 1.3 times the size of Earth (see WWF, 2008). This difference between biocapacity and the global EF is often called overshooting or ecological deficit. Ecological overshooting cannot be sustained indefinitely, and the growing pressure we impose on ecosystems will sooner or later translate into food shortages, biodiversity loss and accelerated climate change.

Larger economies necessarily account for a larger share of the global EF, and dividing each country's footprint by its population provides a measurement of ecological deficit per person (reflecting individual consumption habits as well as the economy's efficiency; see Holden and Linnerud, 2007). It has been estimated that approximately 2 global hectares of productive biosphere are available to each individual on Earth (see, e.g., WWF, 2008; Wackernagel, 2007). Not coincidentally, the US (and Australia initially), apart from not committing themselves to CO_2 reductions under the Kyoto Protocol, also have among the highest EF per head (around 9.5 and 7.5 global hectares in 2008 respectively). The European Union (EU 25) uses an average of 5.8 global hectares per capita, also well above the estimated average capacity threshold of 2 global hectares (WWF, 2008). As developing economies' living standards and greenhouse gas emissions per head converge towards the European or US average over time (coupled with rising populations), the ecological deficit implied by our global footprint will continue to expand. An expansion of middle classes in many developing countries, while reversing a long trend of income inequality, will increase pressure on already degraded ecosystems. Carbon sinks will simply not suffice to constrain increases in carbon dioxide concentrations in the atmosphere and, as temperatures rise and the fragility of ecosystems deteriorate, humanity will be forced by necessity to adjust downwards its EF.

Over the last few years several popular websites of non-governmental organizations (e.g. WWF and the Global Footprint Network) or even government agencies (e.g. the Austrian Ministry of Agriculture, Forestry, Environment and Water Management and the Environment Protection Authority of the State Government of Victoria in Australia) have offered personalized calculators of EFs. These online EF calculators are designed to allow individuals and firms to measure their personal environmental burden and also estimate the ecological deficit at a global scale if every single person on the planet adheres to similar consumption or production standards. Many of the EF tools relate to the overall biocapacity of the planet, although some offer from specialized calculations on water or carbon impacts.

The expansion of online personal calculators in recent years demonstrates the increasing interest of the wider public in assessing the sustainability of their behaviour as consumers.[1] Several studies have offered broad critical assessments of the ways in which EF analysis has been formulated and applied so far (van den Bergh and Verbruggen (1999) and Fiala (2008) offer comprehensive criticisms). Our study approaches the suitability of EF indices as a measure of sustainability from a different angle. We focus our analysis on popular online EF calculators that produce estimates of individual consumer impacts on the Earth in terms of biocapacity, and discuss whether such indices often mislead consumers by suggesting choices of 'sustainable' behaviour that are incapable of reversing the current unsustainable trend of the human enterprise. We have reviewed numerous popular online EF calculators offered for self-assessment of personal consumer impacts and found that surprisingly, even when the most environmentally friendly options are adopted, one still exceeds the planet's biocapacity levels. The main purpose of the paper is not to comment extensively on the methodological construction of these online EF calculators (and possible weaknesses as identified in the next section), which of course influence calculation results. This by itself would be an extremely demanding task, particularly as most websites of online EF calculators do not necessarily provide detailed information on the methodological construction of their indices. Instead, we focus on the nature of the final outcome of such calculations that render even the most environmentally friendly consumption levels as unsustainable. The absence of options to fully offset one's environmental impacts implicitly suggests that there is no truly sustainable level of consumption at current population levels. Although all online EF calculators claim to be a tool for education to promote sustainable behaviour, their calculations suggest, to the contrary, that as consumers we may postpone but not necessarily prevent environmental catastrophes. If the global economy

[1] There is no clear-cut definition of sustainable consumption (although, in the context of EFs, this corresponds to consumption patterns that prevent ecological overshooting, as defined earlier). More broadly, sustainable consumption is often referred to as consumption that has an emphasis on 'minimising resource use, waste and pollution, taking a life-cycle perspective in consumer decision-making and acting with concern for future generations' (see http://www.unesco.org/education/tlsf/TLSF/theme_b/mod09/uncom09t06.htm and UNEP, 2001).

DOI: 10.1002/sd

is currently on an unsustainable path that cannot be avoided, this certainly is not reflected by the rhetoric used on the websites of EF calculators that often claim to set consumers on a sustainable course.

The remainder of the paper is organized as follows. The next section summarizes some of the methodological and policy issues raised in the literature that critique the suitability of the EF more broadly as a sustainability proxy (rather than strictly focusing on online EF calculators). In the third section, we complement the existing debate on the appropriateness of the EF by providing an additional point of critique that has surprisingly received no attention in the literature. Apart from any methodological objections to the way in which existing EF indices are constructed, we argue that the current online EF calculators do not provide, strictly speaking, truly sustainable options that fully mitigate consumers' environmental impacts (possibly reflecting the limitations of any current interventions given available technologies, production and population levels). The main characteristics of footprint calculators are presented, as well as the outcomes when best-scenario choices are adopted. The majority of personalized online calculators surveyed assume ecological overshooting (deficit) even when the most 'environmentally friendly' options are adopted and are found to be limited in the resource-saving options they offer for consumers, such as participation in carbon-offsetting programmes, and/or local production of food. The fourth section offers a way forward.

Existing Criticism of EF Analysis

In principle, the EF concept performs a commendable task by condensing complex and detailed information on individual consumption into an aggregate measure of sustainable production (via a consumption–land-use matrix). The increasing popularity and use of the index, though, demands critical assessment of its assumptions, calculations, suitability and intended aims and effects. Existing critiques mainly focus on methodological weaknesses embedded in the way in which EF indices are constructed; they generally emphasize the need to distinguish among different types of land use and technologies in place, adopt a more dynamic approach that incorporates market signals and take into consideration the spatial characteristics of consumption and production.

Land Use

A common criticism of EF indices relates to their failure to distinguish between sustainable and unsustainable land use (van den Bergh and Verbruggen, 1999; van Kooten and Bulte, 2000; Venetoulis and Talberth, 2008). EF indices, largely based on top-down aggregation of individual effects, usually fail to incorporate localized information of land use and, as a result, consumption categories often translate into the same amount of land cover and impact, despite the fact that certain production processes may entail long-term environmental damage and multiple environmental externalities. While intensive land use (with the use of fertilizers and pesticides) may reduce the EF of food production, it results in groundwater pollution and health damage for the surrounding population (Herendeen, 2000; van den Bergh and Verbruggen, 1999). For this reason, EF assessments need to control for the quality dimension of production (and long-lasting environmental externalities) before converting consumption into biologically productive area (Rapport, 2000). Venetoulis and Talberth (2008) also criticize the EF for failing to allocate space for the needs of non-human species.

Differences in Technology

The EF is a static measure of sustainability that extrapolates global environmental pressure in terms of reproductive land cover from production patterns; therefore, it naturally fails to incorporate the dynamics of change in technology use and consumer behaviour (see Fiala, 2008; Moffatt, 2000). While this might be less problematic when one treats EF impacts in a static way, the analysis becomes less meaningful when one is interested in ecological impacts in a more dynamic context (e.g. in understanding the impacts of future growth in consumption). While EF analysis does not necessarily suffer from such methodological weaknesses when treated as a snapshot of sustainability, this is more problematic for the case of online EF calculators. The online EF calculations usually

DOI: 10.1002/sd

assume that it suffices to simply multiply the average consumption level in the US or Europe by the world population to reach a hypothetical global measure of environmental stress; assuming convergence over time in income per capita and consumption levels between the developing and developed economies. This ignores the fact that technologies of different resource intensity may be adopted across regions and time. While there is evidence of gradual income convergence in recent years, this fails to acknowledge that developing nations may adopt a different set of production technologies (perhaps dirtier at their first stages of economic expansion) or that R&D investment in new, environmentally friendly technologies (e.g. carbon capture and storage) may in time mitigate environmental pressure.

Sequestration

Some further criticism of the EF has focused on the large weight attached to carbon sequestration by natural sinks (mainly forests; see Ayres, 2000; van den Bergh and Verbruggen, 1999). Of course, this over-reliance on carbon sequestration and forest cover merely reflects the enormous role played by fossil fuels in maintaining current production levels and the infancy of alternative technologies for carbon sequestration (e.g. carbon capture and storage); this is not surprising when one considers that the EF is meant to capture a static snapshot of sustainability of current production. This, however, ignores the fact that using reforestation as a means to sequester increasing carbon dioxide emissions, and hence combat climate change, is likely to become an increasingly costly policy option over time (van den Bergh and Verbruggen, 1999). As reforested land increasingly competes with available land for pasture and agriculture, and the productivity of reforested land in terms of biomass declines, the cost of forest conversion will continuously rise to reflect relative scarcity. Such price signals are likely to render less land-intensive carbon mitigation more economic (i.e. investment in renewable energy and energy efficiency).

Spatial Characteristics of Consumption

An important issue raised by several scholars pertains to observed differences in the spatial dimensions of consumption and production (see Grazi *et al.*, 2007; Hubacek and Jiljum, 2003; Levett, 1998; Opschoor, 2000; van den Bergh and Verbruggen, 1999). The emphasis of the EF on consumption often ignores the fact that the ecological deficits associated with domestic consumption and production, respectively, may differ as a result of increased globalization and trade dependency (although more recent EF analysis incorporates trade-corrected consumption and waste flows, whenever data are available). Regions, for instance, that have limited accessibility to resource endowments and adverse climatic conditions may need to import food from distant locations. European countries, with a much higher population density than the global average, by necessity need to import agricultural commodities and primary resources from other resource-producing regions. This suggests that an increase in food consumption may (at least in theory) be achieved more sustainably in a developing country of low population density and direct access to productive land.

Online Ecological Footprint Calculators and Sustainable Behaviour

In recent years and with the expanding number of internet users, the popularity of the EF index has expanded beyond scientists, policy-makers and NGOs. Several environmental organizations and government agencies now offer online calculators of EFs, where each individual internet user can easily calculate his/her own environmental impact and, through multiplication by global population, estimate the corresponding global ecological deficit (overshooting) if everyone on Earth adopted similar consumer habits. Popular websites with EF calculators invite individuals to submit information on personal consumption habits and activities that demand biologically productive land, either via resource use or waste assimilation (e.g. food consumption, travelling, home energy efficiency, transportation, recycling etc). There is a need for instruments, such as the online EF calculators, to act as a policy tool that both informs and helps to transform concern about the environment into 'constructive' action to mitigate

DOI: 10.1002/sd

against further degradation (Ojala, 2007). This is in line with recent evidence in behavioural psychology, suggesting that proactive behaviour can eliminate a great deal of stress in advance when individuals have an optimistic vision for their future and perceive problems as challenges rather than insurmountable threats.[2]

We have surveyed numerous popular online footprint indices offered for self-assessment of personal consumer impacts and found that, surprisingly, for the majority of available calculators, even when the most environmentally friendly options are adopted, one still exceeds the planet's biocapacity levels. The online EF calculators have a uniquely difficult task in trying to both act as a tool to inform the individual of his/her contribution to environmental damage and constructively promote change in behaviour by offering attainable alternatives to existing lifestyles and patterns of consumption. The absence of options to fully offset one's environmental impacts, reflecting the unsustainable state of production at current population levels, may simply render them a doom-saying, off-putting instrument for some individuals and policy-makers. As Bardwell (1991) highlights, 'fatalistic pessimism' often results when environmental problems are viewed as 'so big nothing can be done' (p. 610). Consumers choosing the best available options in terms of energy-saving, recycling and sustainable consumption are still deemed and implicitly criticized as being unsustainable rather than 'rewarded' for their prudent behaviour.

Environmental degradation poses a unique problem to the individual, in terms of both understanding the extent and linkage of environmental issues, and perceived and actual ability to address and, perhaps, positively influence change towards reducing impacts. Although online EF calculators perform in principle a commendable service by condensing personal information on consumption needs into a single measure of (un)sustainable behaviour and demand for ecologically productive land (in global hectares), they largely fail to act as a planning tool designed to translate sustainability concerns into public action, as was originally suggested by Wackernagel and Rees (1996).

Table 1 provides a list of some of the most popular online EF calculators. Although the list is by no means exhaustive, we make reference to those indices with the highest returns according to the popular Google search engine (under the words 'ecological footprint calculator'). There are numerous other indices available, but they are significantly less comprehensive and utilized, and provide even less guidance about altering behaviour in order to reduce individual pressure on global resources. The WWF calculator is perhaps the most popular calculator and promises to 'set you on a life changing journey'. Other calculators, offered by environmental NGOs (i.e. Global Footprint Network (GFN), Best Foot Forward (BFF)), charitable organizations (i.e. BioRegional (BR)) and government agencies (i.e. the Austrian Ministry of Agriculture, Forestry, Environment and Water Management (ÖF), are set up in a similar fashion and take a similar amount of time to complete. The EF calculator by the environmental NGO Redefining Progress (RP) is the most comprehensive index we surveyed in terms of location-specific consumption, allowing purchase of carbon-offsetting credits, recycling of most materials and options for one's own food production. The provision of information after each question about why a certain option is 'greener' than another is particularly useful, thus directing the consumer to improved choice making to reduce the global footprint.

Organization	Website
World Wide Fund for Nature (WWF)	www.footprint.wwf.org.uk
Global Footprint Network (GFN)	www.footprintnetwork.org/en/index.php/GFN/page/calculators
Best Foot Forward (BFF)	www.ecologicalfootprint.com
Ökologischer Fußabdruck (ÖF) – Austrian Ministry of Agriculture, Forestry, Environment and Water Management (Lebensministerium)	www.mein-fussabdruck.at
BioRegional (BR)	www.calculator.bioregional.com
Redefining Progress (RP)	www.myfootprint.org

Table 1. List of EFs

[2]This is often referred to as *proactive coping*, see for instance Aspinwall and Taylor, 1997; Greenglass, 2002; Schwarzer, 2000.

DOI: 10.1002/sd

In Table 2, we summarize the greenest scenarios offered by these EF websites and the implicit global footprint associated with them (assuming that every single person on the planet adheres to the 'greenest' consumption or production standards). The main purpose is not, strictly speaking, to analyse the methodological construction of these online EF calculators: by itself an extremely demanding and challenging task given the often limited information on methodological details provided by the hosting institutions. Differences in their methodological construction make these EF calculators incomparable by necessity. Instead, we focus on the qualitative aspects of such calculations that situate even the most environmentally friendly consumption levels as unsustainable. We divide the 'greenest' responses according to the following broad categories: income, food consumption, transportation, housing, other consumption, recycling and carbon-offsetting (which we further divide into subgroups where disaggregated information is available). For example, under the 'food' classification, we quote the least EF-intensive responses referring to meat consumption, including the purchase of organic and local food, as well as own food growing. The last rows of the table refer to the corresponding EF when the most environmentally friendly options quoted are selected. All calculators refer to planets needed to sustain lifestyle if such consumer habits are universally adopted, while some link these to attributed global hectares and CO_2 emissions per person. In all but the Redefining Progress (RP) index (last column of Table 2), adopting the most environmentally friendly strategies still results in ecological overshooting (by at least a fifth of earth's total biocapacity). The EF by RP provides the only calculator that links environmentally friendly and resource-saving behaviour to an ecological surplus (with only 0.23 planets needed to sustain lifestyle for the greenest scenario), thus allowing the average consumer to make choices that result in truly sustainable consumption patterns. This is made possible by not confining carbon sequestration to forests and allowing for the purchase of carbon-offsetting credits, extensive recycling and multiple land use (in effect augmenting the estimated Earth's total biocapacity compared with other EF calculators).[3] The majority of online EF calculators, hence, do not allow for a sustainable future, in the sense that global consumption needs are met within the Earth's biocapacity limits. Adopting the least-impact consumer options available may reduce unsustainable practices, but fails nevertheless to turn ecological deficits into surpluses.

A Way Forward

There has been a rapid increase in the popularity of the EF as a sustainability index that translates resource demands for different consumption uses into a common comprehensible measure of environmental impact and ecological overshooting. The EF index can potentially help the average individual understand his/her EF, and operate as a useful indicator of global ecological overshoot (Cortese, 2003; Sutcliffe *et al.*, 2008). At the same time, there are multiple issues surrounding the accuracy of the calculation of the EF in terms of how it estimates this overshooting, and thus what impact it will ultimately have on changing consumer behaviour. While the EF may provide a measure of excessive consumption as well as a benchmark for sustainability (WWF, 2008), in practice there are a number of areas in which it could be improved to act as a tool for education for sustainable behaviour (Sutcliffe *et al.*, 2008).

Despite the unequivocal scientific evidence that the human race is collectively living beyond its means (ecological overshoot), education for more sustainable behaviour is generally compromised by longstanding behaviour and beliefs that can either delay or prohibit a shift in action towards more sustainable outcomes. In promoting sustainability in higher education, Cortese (2003, p. 17) notes the following common assumptions, which act as barriers to integrating different values, increasing awareness and promoting change in behaviour.

- Humans are the dominant species and separate from the rest of nature.
- Resources are free and inexhaustible.
- Earth's ecosystems can assimilate all human impacts.
- Technology will solve most of society's problems.
- All human needs and wants can be met through material means.
- Individual success is independent of the health and well-being of communities, cultures, and the life support system.

[3] For more details on its construction see Venetoulis and Talberth, 2008, as well as the website of Redefining Progress.

DOI: 10.1002/sd

	WWF	GFN	BFF	ÖF	BR	RP
Income						<$19 000 (per year per household)
Food						
Meat	vegan	vegan	vegan	vegan	vegan	vegan
Organic products	buy always			most of the time	most of the time	most of the time
Local products	buy always	buy always	mostly	yes	most of the time	buy always
Grow own food					yes	yes (100 m^2 garden)
Transport						
Personal vehicle	no ownership	no ownership	no ownership	no ownership	no ownership	no ownership
Train use	<25 h per week	none	none	none	none	none
Bus use	<10 h per week	none	none	none	none	none
Air travel	none	none	none	none	none	none
Housing						
Housing type	flat	flat or green design residence	zero emission development	flat (>10 house-block, 55 m^2, sole property owned)	flat (3 bedrooms)	flat (<50 m^2)
House construction		timber		built after 2000		timber
House location						rural
Shared accommodation	>5 adults	>7	>6	7	>6	>5
Heating	gas			communal/biomass	gas	gas
House temperature	11–14°C					low thermostat
Conventional electricity		no use		renewable sources		gas/biomass
Renewable energy		75–100% of use		own solar panels + purchase from green energy providers	100% of use	100% of use
Gas/electr. expenditure		$14 per month				
Electric appliances	regularly off or on stand-by			regularly off or on stand-by/ energy-efficient appliances	regularly off/energy-efficient appliances	regularly off or on stand-by
Energy saving bulbs	yes			>75%	yes	yes
Loft insulation	yes			yes	yes	yes
Cavity wall insulation	yes			yes	yes	yes
Efficiency boiler	yes				yes	yes

DOI: 10.1002/sd

	WWF	GFN	BFF	ÖF	BR	RP
Double glazing	yes			yes	yes	
Water-saving appliances				yes	yes	yes
Other house items	minimum expenditure	minimum expenditure		minimum expenditure	minimum expenditure	minimum expenditure
Other consumption						
Pets	no ownership					
Jewellery/DIY tools	no expenditure (last 12 months)				no expenditure (last 12 months)	
Cosmetics	£0–100 (last 12 months)				no expenditure (last month)	
Clothing		minimum expenditure			no expenditure (last month)	
Buy recycled products					frequently	almost always
Recycling				minimum waste (<1 bag per week)		
Waste composting	yes				yes	
Recycling:						
Paper	yes	yes	yes		yes	yes
Tin cans	yes		yes		yes	yes
Plastic	yes	yes	yes		yes	yes
Glass	yes		yes		yes	yes
Electronics			yes		yes	yes
Carbon off-setting						yes
Ecological footprint						
Planets to sustain lifestyle	1.36	2.30	1.30	1.20	1.20	0.23
Global hectares		4.16	2.20	2.10	2.20	3.68
Annual tonnes of CO_2	16.43	10.30	4.10		4.80	(0.6 gha)

Table 2. Footprints for ‘greenest’ scenarios
The GFN EF is country specific (US or Australia). In our example, we have calculated the index assuming US residence, although this makes no qualitative difference to the results. The Redefining Progress (RP) EF is also country specific and in the above calculations we have assumed a UK residence.

DOI: 10.1002/sd

Furthermore, EFs, with their focus on static measurements of sustainability, fail to capture the contribution of population growth to global ecological overshooting. Our global collective footprint largely depends on the total world population, which has experienced a sixfold increase since the beginning of the 19th century.[4] The marginal effect of a single individual's unsustainable consumption behaviour will, therefore, have a more severe impact on a planet with a rapidly rising population, where there is insufficient time for the regeneration of non-renewable resources. In the case of climate change, equal increases in carbon emissions will have disproportionately larger impacts on climate stability in the future (see FitzRoy and Papyrakis, 2010).

The EF, as it is currently designed, suffers from a Western bias with a 'top-down', aggregated method of individual EFs based on present consumption patterns in the developed world. It does not, therefore, readily incorporate variation in consumer behaviour within or between countries, nor does it reflect factors demonstrated to be important in promoting improved individual action towards the environment, such as environmental values, situational factors (e.g. demographic variation and local knowledge) and/or psychological variables (e.g. intrinsic motivation, environmental citizenship) (Barr, 2004). At present, most individuals in the developing world have a minimal contribution to our global overshooting; however, with expanding middle classes, the adoption of Western lifestyles and increased demand for meat consumption, the EF will necessarily need to pay more attention to challenges arising from emerging economies.

In this context, Saravanamuthu (2006a, 2006b, 2009) has suggested a three-dimensional framework through which sustainability and its measurements can be conceptualized. First, there is scope for *customized accountability* that synthesizes localized (micro) information and indigenous knowledge in an effort to solve universal (macro) challenges. EFs are often constructed as a 'one size fits all' methodological tool, with little attempt to integrate localized and often fragmented knowledge on spatio-temporal elements of sustainability (e.g. on specific types of land and technology use, differences in land quality, cultural characteristics and expected changes in behaviour). Second, there is a need to reduce the *dichotomization between means and ends*, so that particular emphasis is placed on the interconnectedness between individual actions and impacts across time and space. As we have emphasized, the EF is often constructed as a static measure of sustainability, with little attention to the dynamics of change with respect to technology adoption and abatement (sequestration) methods. It is crucial that causal relationships between human activities (means) and environmental outcomes (ends) are clearly defined in a way that incorporates dynamic information on the positive and negative externalities of individual behaviour on collective outcomes (society, environment). Third, Saravanamuthu (2006a, 2006b, 2009) emphasizes the need to increase *reflexivity* in sustainability planning. Again, individuals are more likely to reflect on their own consumer practices (and hence revisit and modify these over time) when they have a clear understanding of environmental challenges and are able to associate personal behaviour with harmful outcomes. Methodological transparency of how EFs are constructed can further increase proactive (reflective) behaviour amongst consumers. If such aspects could be more readily incorporated, the EF calculator would then act as a more constructive tool as it would incorporate local circumstances and connectivity between environmental goods and services and human use, as well as improving personal accountability. Sutcliffe *et al.* (2008) conducted a study to assess the use of an EF approach at the household level and found that greater personalization of the EF analysis encouraged changes in behaviour leading towards less consumer-intensive lifestyles.

Over the last few years, several popular websites have offered more personalized calculators of EFs, claiming that this could incentivize individuals to alter current behaviour and consumption patterns. As we have demonstrated, most online EF calculators suggest ecological overshooting irrespective of consumer behaviour and eco-friendliness; this result could potentially have the opposite of the intended effect and discourage consumers from improving their behaviour further. As we have highlighted, one notable exception is the Redefining Progress (RP) calculator, which presents a much more comprehensive set of questions around actions to reduce waste and offset carbon, and clearly identifies the associated environmental benefits of the more 'sustainable' choices. Websites of EF calculators that attach negative ecological deficits even to the best options and most prudent consumer choices should highlight the current unsustainable state of human production under current technologies in place and population levels and the limitations of personal interventions to reverse this (at least at present). The online EF

[4] The Nobel-prize chemist Paul Crutzen refers to the last two centuries as the 'Anthropocene' age – in effect, a distinctive geological era due to the significant impacts of the human population on the natural environment (see Crutzen, 2002).

DOI: 10.1002/sd

calculators need to become an effective tool for educating the consumer about the sustainable and unsustainable nature of one's lifestyle – arguably the intended purpose of the EF calculators to begin with, but a role they have not been able to play due to current design. In order to communicate the need for sustainable behaviour and the impacts of our individual actions, the indicators can act as a powerful signal if they are designed with the purpose of educating the user on the various impacts of different lifestyle choices, clearly frame the problem and present options that prevent ecological deficits. In order to accomplish this, they will necessarily need to incorporate more detailed localized information (on any spatio-temporal differences in technologies and behaviour), integrate a more dynamic analysis of key variables, illustrate clearly the links between individual action and aggregate environmental impacts, describe in detail their methodological construction and revise these whenever new information becomes available.

Acknowledgements

The authors are grateful to two anonymous reviewers and Jeroen van den Bergh for comments on an earlier draft. The authors received helpful comments from several participants at the Eighth International Conference of the European Society for Ecological Economics (ESEE) in Ljubljana, Slovenia (29 June–2 July 2009). All remaining errors are ours.

References

Aspinwall LG, Taylor SE. 1997. A stitch in time: self-regulation and proactive coping. *Psychology Bulletin* **121**: 417–436.

Ayres RU. 2000. Commentary on the utility of the ecological footprint concept. *Ecological Economics* **32**: 347–349.

Bardwell LV. 1991. Problem-framing: a perspective on environmental problem-solving. *Environmental Management* **15**: 603–612.

Barr S. 2004. What we buy, what we throw away and how we use our voice. Sustainable household waste management in the UK. *Sustainable Development* **12**: 32–44.

Cortese A. 2003. The critical role of higher education in creating a sustainable future. *Planning for Higher Education* **31**: 15–22.

Crutzen PJ. 2002. Geology of mankind. *Nature* **415**: 23.

Fiala N. 2008. Measuring sustainability: why the ecological footprint is bad economics and bad environmental science. *Ecological Economics* **67**: 519–525.

FitzRoy F, Papyrakis E. 2010. *An Introduction to Climate Change Economics and Policy*. Earthscan: London.

Grazi F, van den Bergh JCJM, Rietveld P. 2007. Spatial welfare economics versus ecological footprint: modelling agglomeration, externalities and trade. *Environmental and Resource Economics* **38**: 135–153.

Greenglass E. 2002. Proactive coping and quality of life management. In *Beyond Coping: Meeting Goals, Vision, and Challenge*, Frydenber E (ed.). Oxford University Press: London; 37–62.

Herendeen RA. 2000. Ecological footprint is a vivid indicator of indirect effects. *Ecological Economics* **32**: 357–358.

Holden E, Linnerud K. 2007. The sustainable development area: Satisfying basic needs and safeguarding ecological sustainability. *Sustainable Development* **15**: 174–187.

Hubacek K, Jiljum S. 2003. Applying physical input–output analysis to estimate land appropriation (ecological footprints) of international trade activities. *Ecological Economics* **44**: 137–151.

Levett R. 1998. Footprinting: a great step forward, but tread carefully. *Local Environment* **3**: 67–74.

Moffatt I. 2000. Ecological footprints and sustainable development. *Ecological Economics* **32**: 359–362.

Ojala M. 2007. Confronting macro-social worries: worry about environmental problems and proactive coping among a group of young volunteers. *Futures* **39**: 729–745.

Opschoor H. 2000. The ecological footprint: measuring rod or metaphor? *Ecological Economics* **32**: 363–365.

Rapport DJ. 2000. Ecological footprints and ecosystem health: complementary approaches to a sustainable future. *Ecological Economics* **32**: 367–370.

Saravanamuthu K. 2006a. Emancipatory accounting and sustainable development: a Gandhian–Vedic theorisation of experimenting with truth. *Sustainable Development* **14**: 234–244.

Saravanamuthu K. 2006b. Gandhian–Vedic paradigm: theorising sustainable development. In *Methodological Issues in Accounting Research: Theories and Methods*, Hogue Z (ed.). Spiramus: London; 291–338.

Saravanamuthu K. 2009. A journey of socialising the risks associated with global warming: a Gandhian insight into Schumacher's total accounting and accountability. *Advances in Public Interest Accounting* **14**: 121–189.

Schwarzer R. 2000. Manage stress at work through preventive and proactive coping. In *The Blackwell Handbook of Principles of Organizational Behavior*, Locke E (ed.). Blackwell: Oxford; 342–355.

Sutcliffe M, Hooper P, Howell R. 2008. Can eco-footprinting analysis be used successfully to encourage more sustainable behaviour at the household level? *Sustainable Development* **16**: 1–16.

DOI: 10.1002/sd

United Nations Environment Programme (UNEP). 2001. *Consumption Opportunities: Strategies for Change*. UNEP: Paris.
van den Bergh JCJM, Verbruggen H. 1999. Spatial sustainability, trade and indicators: an evaluation of the 'ecological footprint'. *Ecological Economics* **29**: 61–72.
van Kooten GC, Bulte EH. 2000. The ecological footprint: useful science or politics? *Ecological Economics* **32**: 385–389.
Venetoulis J, Talberth J. 2008. Refining the ecological footprint. *Environment, Development and Sustainability* **10**: 441–469.
Wackernagel M. 2007. Can we afford to reduce our ecological footprint? In *Making Peace with the Earth*, Bindé J (ed.). Berghahn: Oxford; 85–98.
Wackernagel M, Rees W. 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth*. New Society: Gabriola Island.
Wackernagel M, Rees W. 1997. Perceptual and structural barriers to investing in natural capital: economics from an ecological footprint perspective. *Ecological Economics* **20**: 3–24.
Wackernagel M, Schulz NB, Deumling D, Linares AC, Jenkins M, Kapos V, Monfreda C, Loh J, Myers N, Norgaard R, Randers J. 2002. Tracking the ecological overshoot of the human economy. *Proceedings of the National Academy of Sciences* **99**: 9266–9271.
World Wide Fund for Nature (WWF). 2008. *Living Planet Report*. Gland, Switzerland: WWF.

DOI: 10.1002/sd